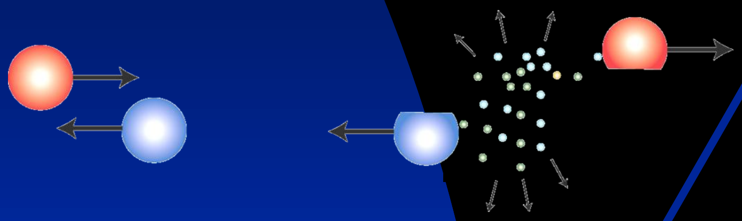
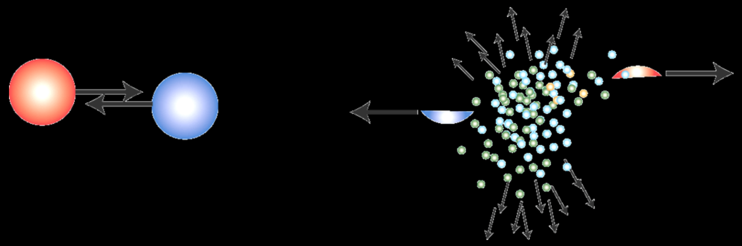
EOS SAMURAI-TPC

Department of Physics
Kyoto University
Tetsuya MURAKAMI





T. Murakami[a], Jiro Murata[b], Kazuo Ieki[b], Shunji Nishimura[c], Yoichi Nakai[c], Betty Tsang[d], Bill Lynch[d], Dan Coupland[d], Abigail Bickley[d], Michael A. Famiano[e], Lee Sobotka[f], Robert Charity[f], Demetrios Sarantites[f], Sherry Yennello[g], Roy Lemmon[h], Abdou Chbihi[i], Giuseppe Verde[j], Z.Y. Sun[k], Wolfgang Trautmann[l]
[a]Kyoto University, [b]Rikkyo University, [c]RIKEN, Japan, [d]NSCL Michigan State University, [e]Western Michigan University, [f]Washington University, [g]Texas A&M University, USA, [h]Daresbury Laboratory, [i]GANIL, France, UK, [j]LNS-INFN, Italy, [k]IMP, Lanzhou, China, [l]GSI, Germany

About six-seven years ago

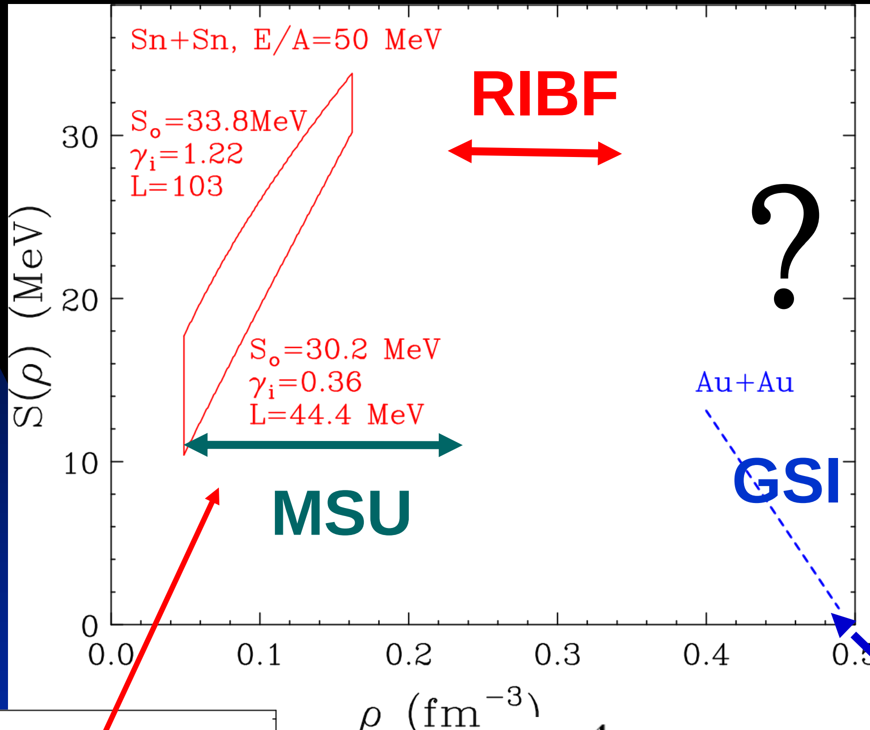
Bill Lynch and I started discussing on possible nuclear reaction experiments using RIBF.

$$E(\rho,\delta) = E(\rho,0) + E_{sym}(\rho)\delta^2$$

$$\delta \equiv (\rho_n - \rho_p)/\rho$$

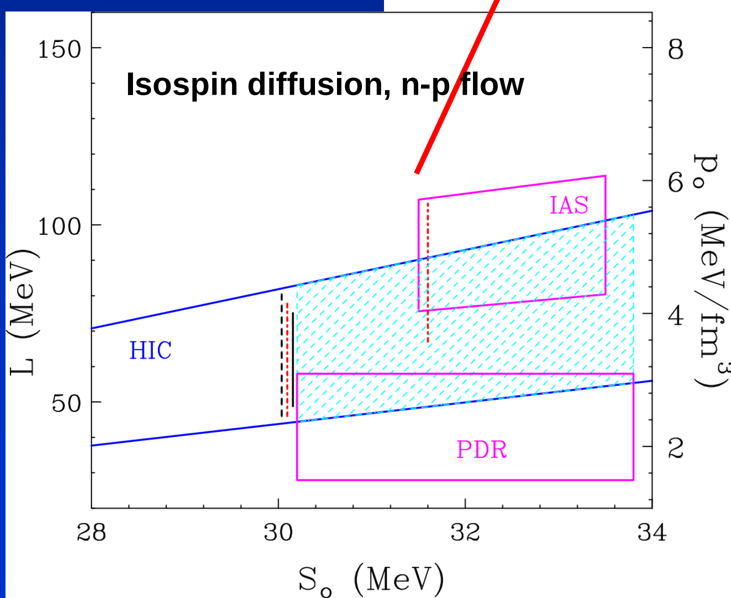
$$E_{stm}(\rho) \equiv \frac{1}{2}\frac{\partial^2 E(\rho,\delta)}{\partial \delta^2}\bigg|_{\delta=0} = E(\rho,1) - E(\rho,0)$$

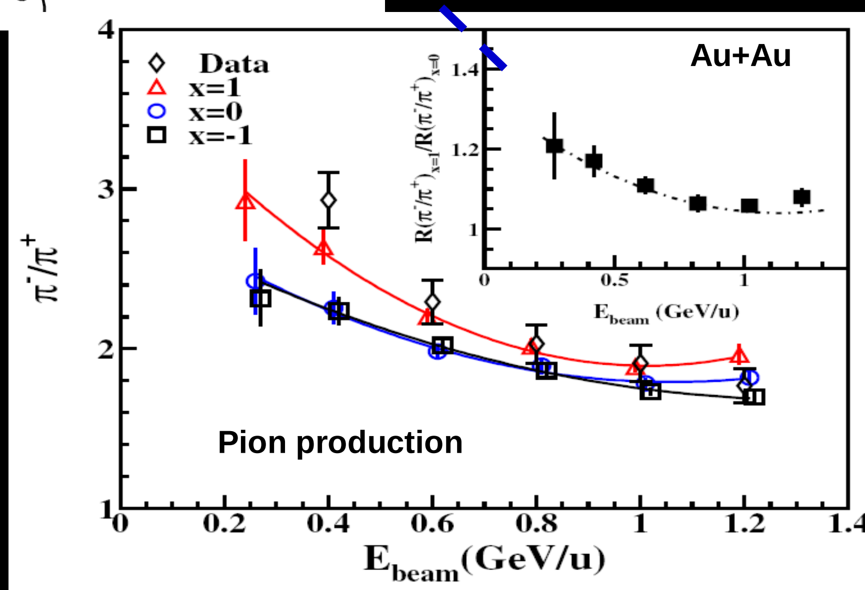
Constraining the symmetry energy at supra-saturation densities $\rho \approx 2\rho_0$.



RIBF can constrain the symmetry energy at ~ $2\rho_0$.

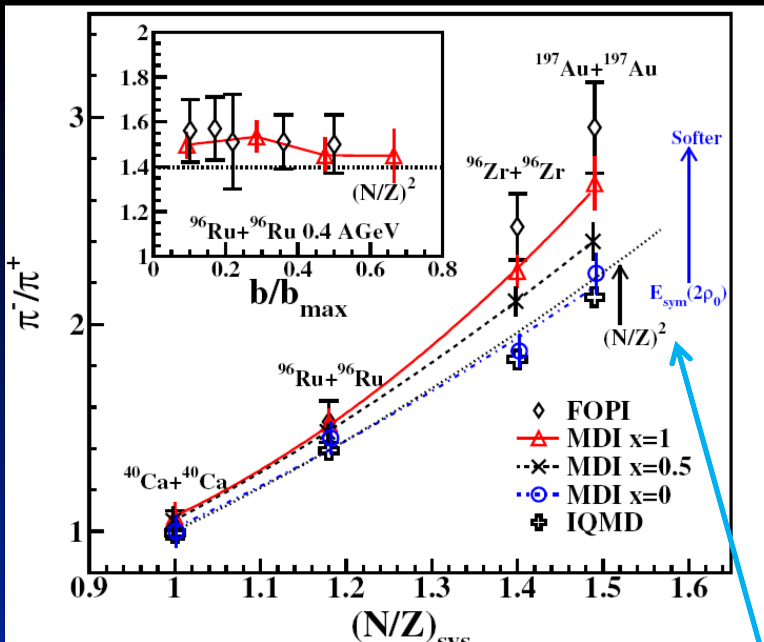
Requires data with controlled variations in system asymmetry



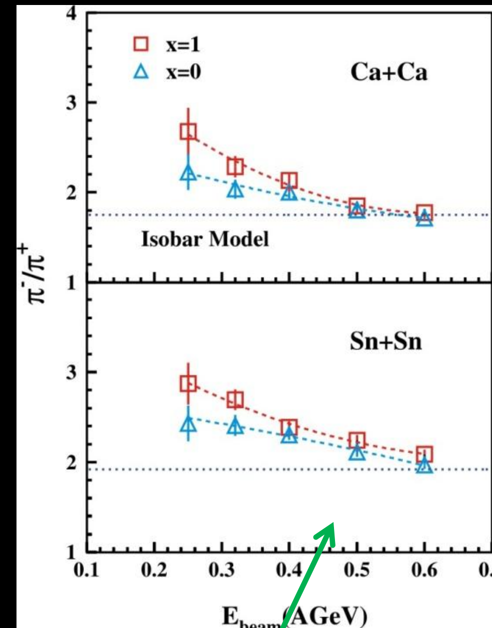


Xiao, et al., arXiv:0808.0186 (2008)
Reisdorf, et al., NPA 781 (2007) 459.

Choice of beams and facilities for pion ratios



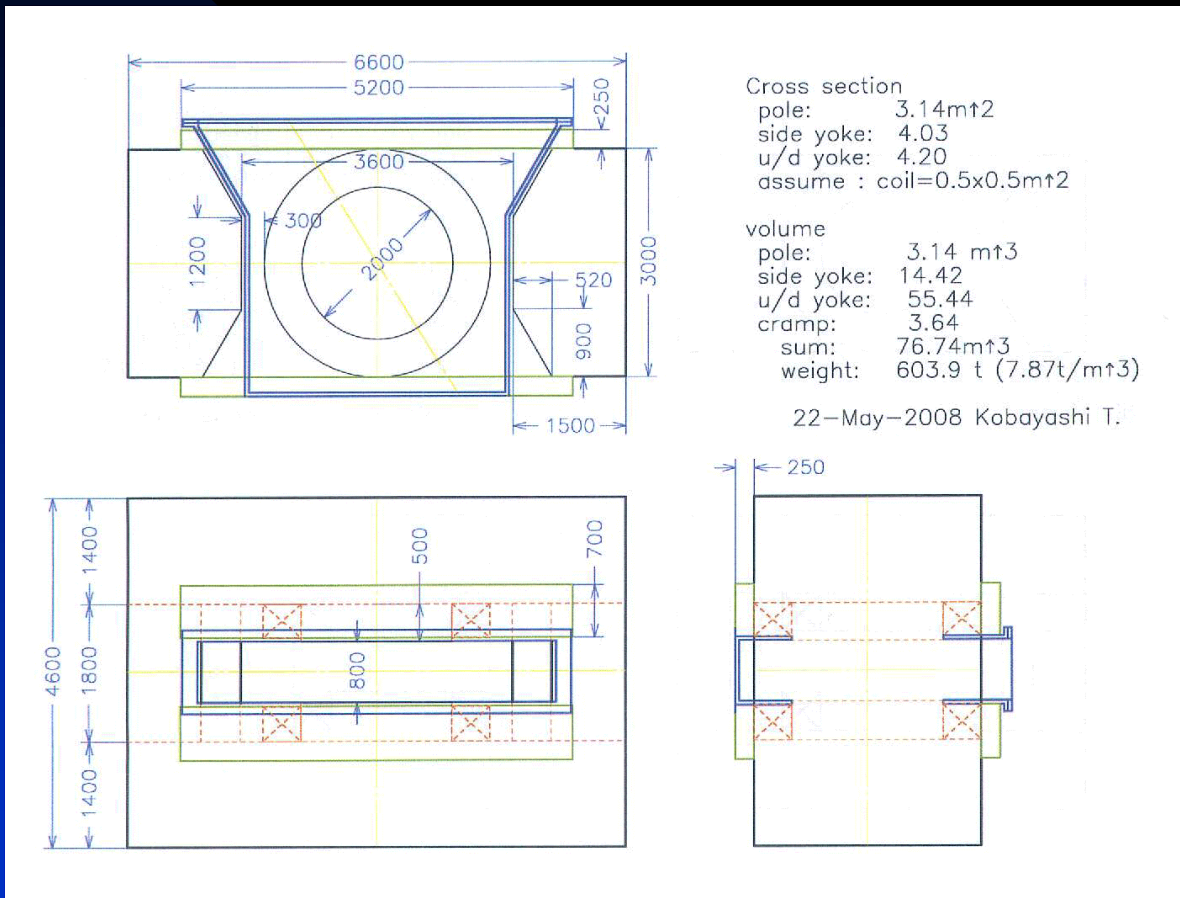
Xiao, et al., arXiv:0808.0186 (2008)
Reisdorf, et al., NPA 781 (2007) 45



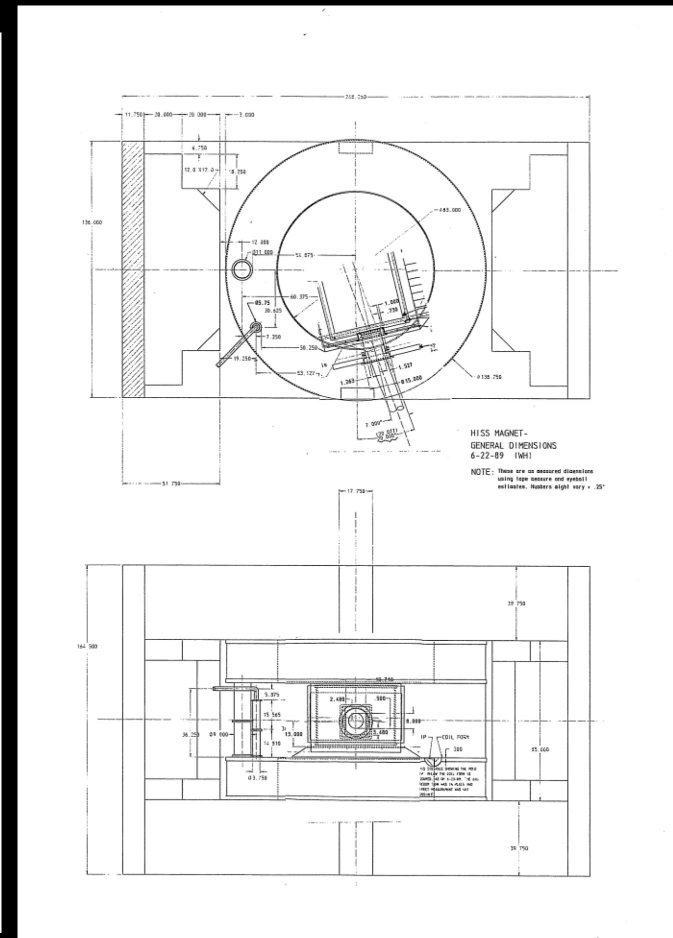
Zhang et al., arXiv:0904.0447v2 (2009)

- Choice of facility is governed by availability of beams and equipment:
- Sensitivity to symmetry energy is larger for neutron-rich beams
  - Largest sensitivity requires rare isotope beams such as ^{132}Sn and ^{108}Sn.
- Sensitivity increases with decreasing incident energy.
- Most sensitive measurements of π^-/π^+ ratios would be with beams available at RIBF or FAIR.
- Measurements require floor-space and a magnet suitable for a TPC; this is not currently within the FAIR project.

Comparison of SAMURAI with EOS(HISS)



Gap ~80 cm(expected)



Gap=100 cm

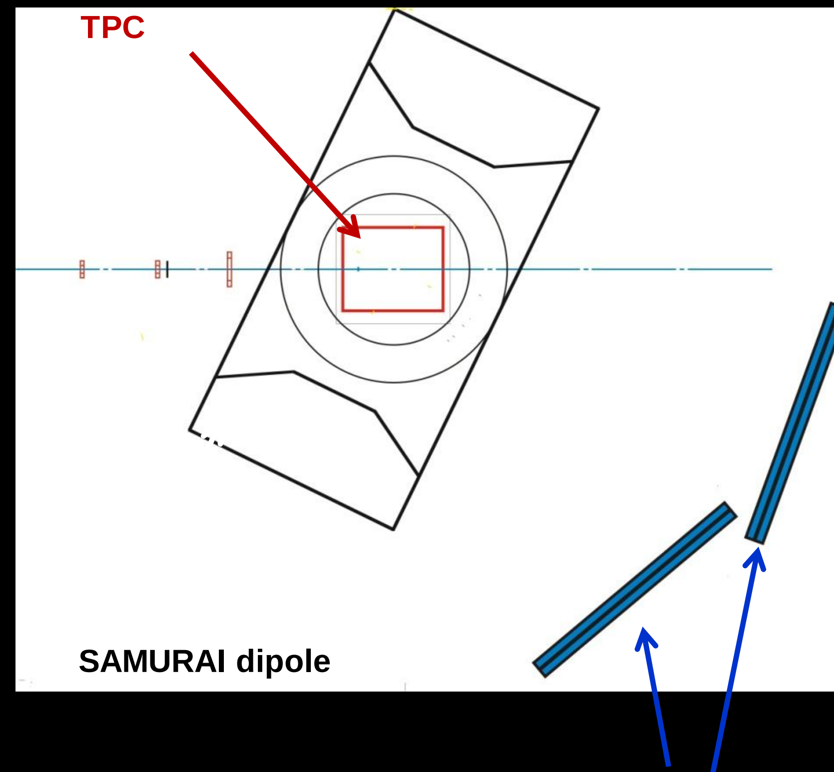
Device: SAMURAI TPC

Device: SAMURAI TPC

Propose to build a TPC for use within the gap of the SAMURAI dipole.

The SAMURAI TPC would be used to constrain the density dependence of the symmetry energy through measurements of:

- Pion production
- Flow, including neutron flow measurments with the nebula array.



Nebula scintillators

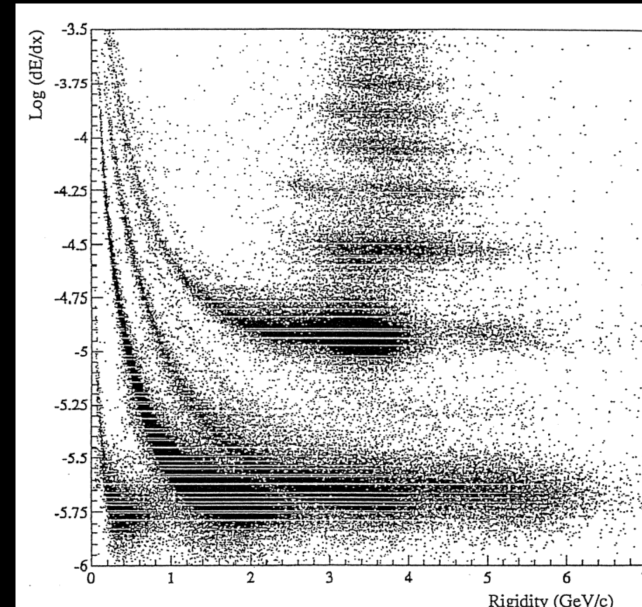
Proposed Research program

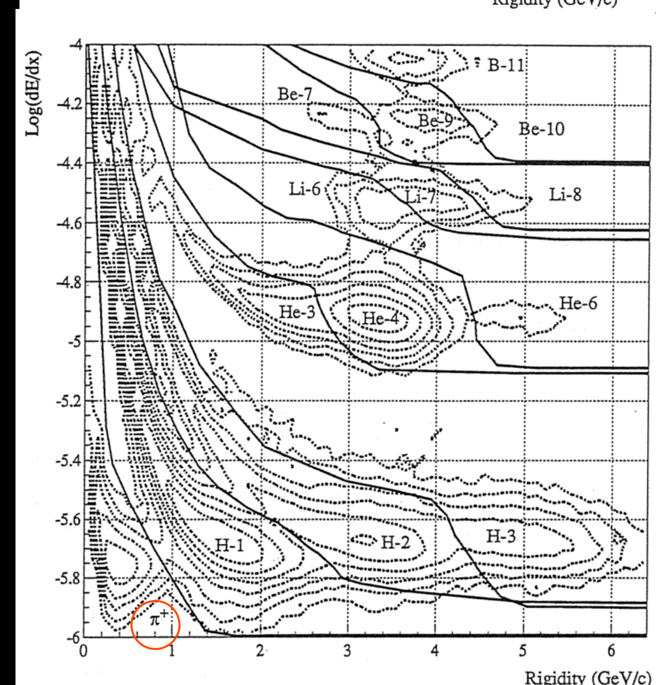
Probe	Devices	E_{lab}/A (MeV)	Part./s	Main Foci	Possible Reactions	FY
$\pi^+\pi^-$,p, n,t,^{3}He	TPC Nebula	200-300 350	10^4-10^5	E_{sym} m_n^*, m_p^*	^{132}Sn+^{124}Sn, ^{105}Sn+^{112}Sn, ^{52}Ca+^{48}Ca, ^{36}Ca+^{40}Ca ^{124}Sn+^{124}Sn, ^{112}Sn+^{112}Sn	2013 -2014
$\pi^+\pi^-$ p, n,t,^{3}He	TPC Nebula	200-300	10^4-10^5	σ_{nn},σ_{pp} σ_{np}	^{100}Zr+^{40}Ca, ^{100}Ag+^{40}Ca, ^{107}Sn+^{40}Ca, ^{127}Sn+^{40}Ca	2015 -2017

- Typical rates at 10^4/s are 3-4 pions/s of each charge and about 5 n's/s
  - Goal is to run up to 10^5 /s

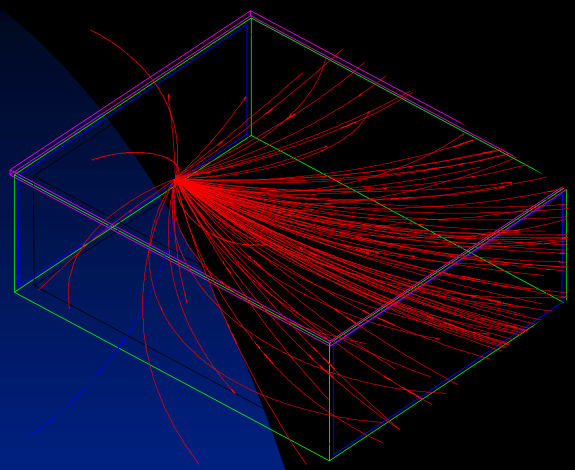
Performance of EOS-TPC

HISS TPC Characteristics	
Pad Plane Area	1.5m × 1.0m
Number of Pads	15360 (120 × 128)
Pad Size	12mm × 8mm
Drift Distance	75 cm
Time Sampling Freq.	10 MHz
Signal Shaping Time	250 ns
Electronic Noise	$\boxed{\text{700 e}}$
Gas Gain	$\boxed{3000}$
Gas Composition	$90\% Ar + 10\% CH_4$
Pressure	1 Atmosphere
B Field	13 kG
E Field	120 V/cm
Drift Velocity	5cm/μ s
Event Rate	10-80 events/ 1 sec spill
dE/dx range	Z = 1-8, $\Lambda, \pi, p, d, t, He, Li - O$
Two Track Resolution	2.5cm
Multiplicity Limit	≈ 200





TPC properties



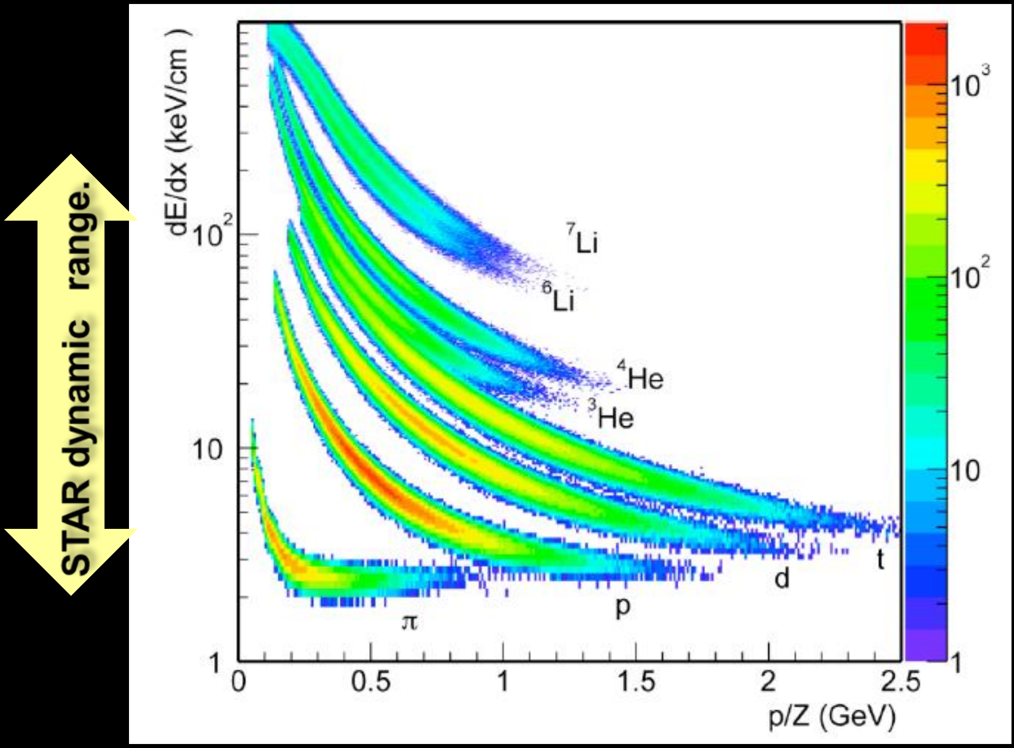
GEANT simulation
$^{132}Sn+^{124}Sn$ collisions at E/A=300 MeV

- **Good efficiency for pion track reconstruction is essential.**
- **Initial design is based upon EOS TPC, whose properties are well documented.**

SAMURAI TPC parameters	
Pad plane area	1.3m x 0.9 m
Number of pads	11664 (108 x 108)
Pad size	12 mm x 8 mm
Drift distance	55 cm
Pressure	1 atmosphere
dE/dx range	Z=1-3 (Star El.), 1-8 (Get El.)
Two track resolution	2.5 cm
Multiplicity limit	200 (large systems absolute pion eff.)

Electronics upgrade

- Initial experiments 2013-2014 would be performed with STAR TPC electronics.
  - Used at MSU for S800 spectrograph and tracking detectors.
- STAR ADC is 10 Bit; data rate is <100 events/s.
  - Limits dynamic range of resolved particles
- To increase dynamics range and resolution, new GET electronics, would be installed in 2014.



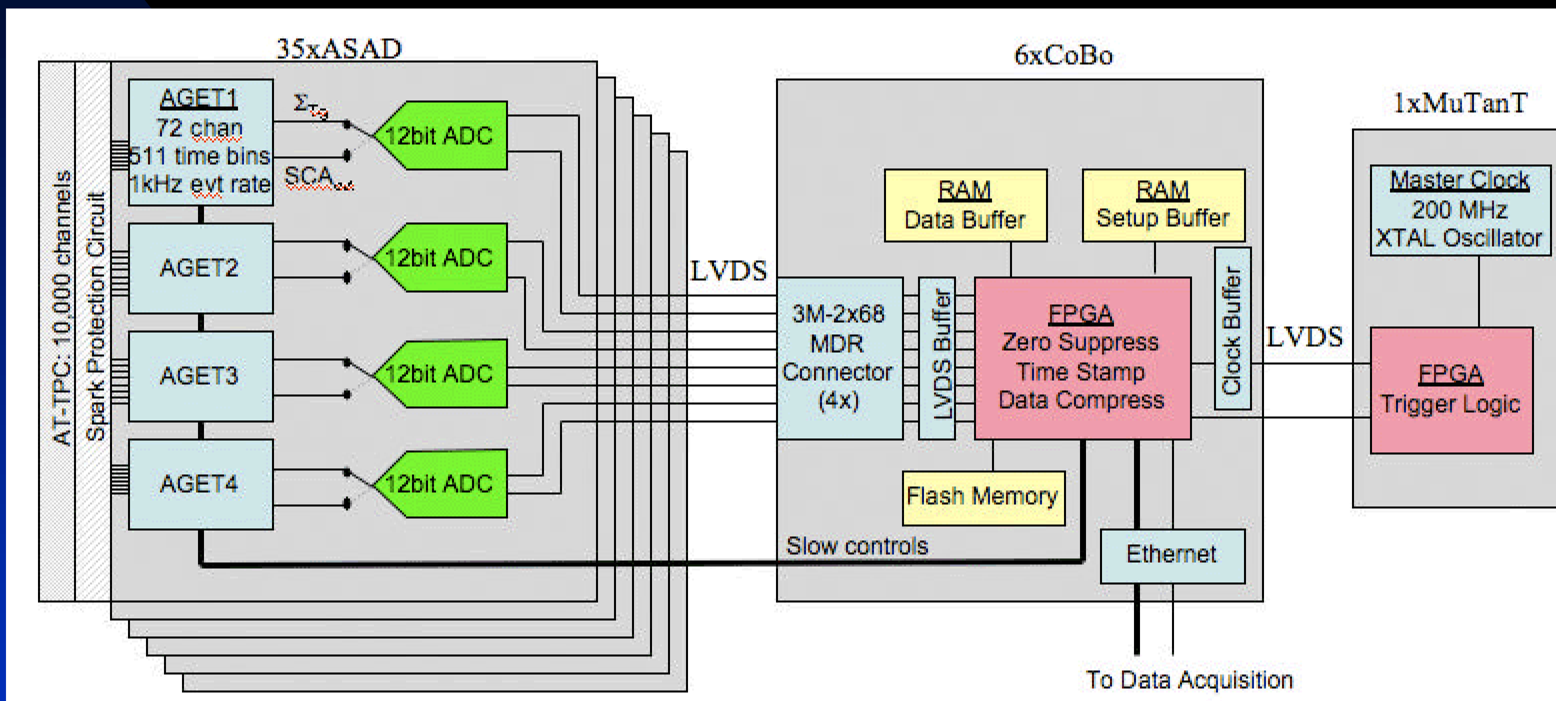
resolution of SAMURAI TPC,
nSimulated eglecting ADC dynamical range problem.

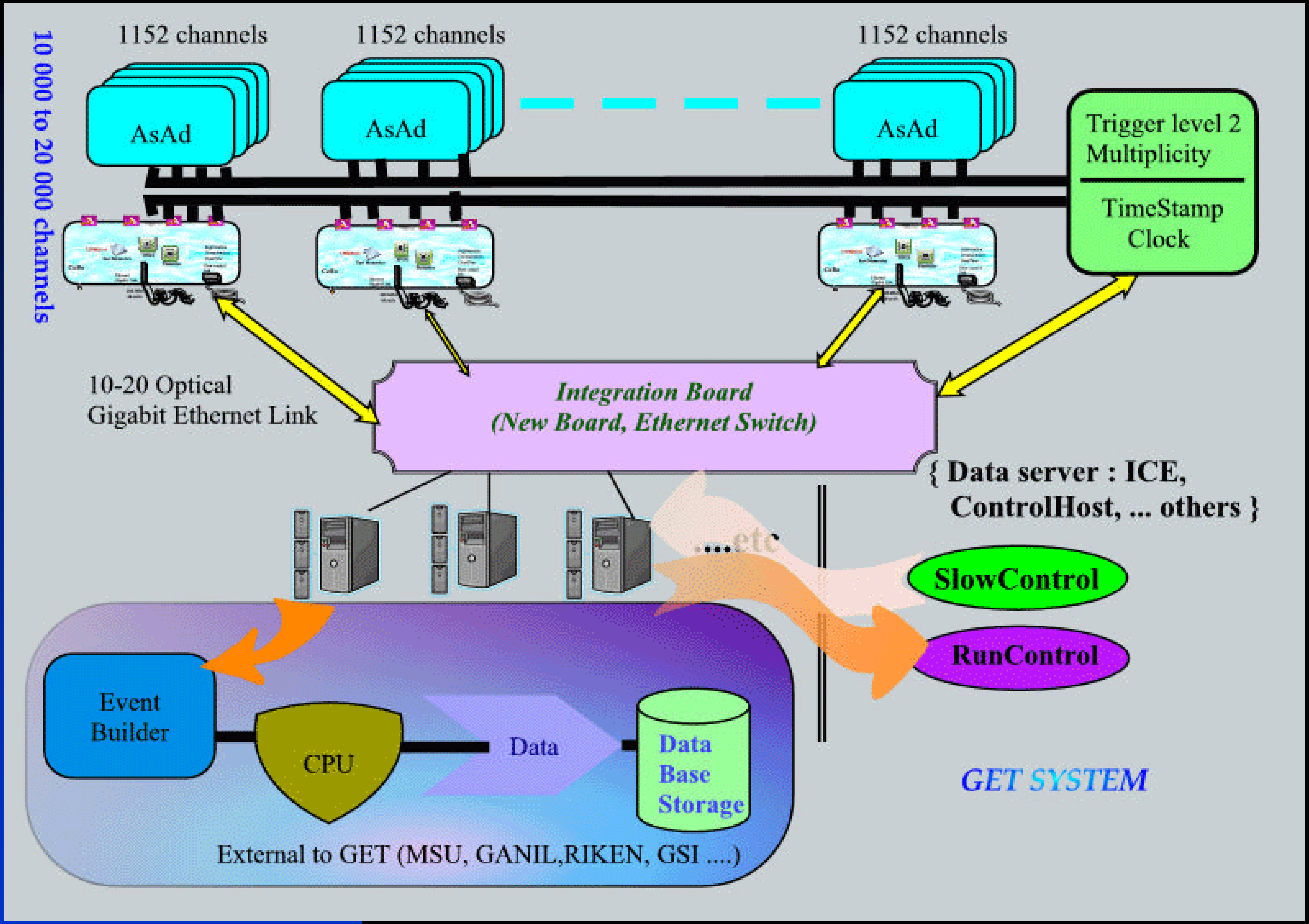
GET:
GENERAL ELECTRONICS FOR TPC

Coordination Board:

Abigail Bickley	**NSCL/MSU**
Atsushi Taketani	**RIKEN**
Bertram Blank	**CENBG**
Jean-Louis Pedroza	**CENBG**
Emanuel Pollacco	**IRFU/Saclay**
Patricia Chomaz	**GANIL**
Ricardo Raabe	**GANIL**
Tetsuya Murakami	**Kyoto/RIKEN**
Frederic Druillole	**IRFU/Saclay**
Wolfgang Mittig	**NSCL/MSU**

Preparing MOU


35xASAD
AT-TPC: 10,000 channels
Spark Protection Circuit
AGET1
72 chan
511 time bins
1kHz evt rate
SCA
12bit ADC
AGET2
12bit ADC
AGET3
12bit ADC
AGET4
12bit ADC
LVDS
6xCoBo
RAM
Data Buffer
RAM
Setup Buffer
3M-2x68
MDR
Connector
(4x)
LVDS Buffer
FPGA
Zero Suppress
Time Stamp
Data Compress
Clock Buffer
Flash Memory
Slow controls
Ethernet
To Data Acquisition
LVDS
1xMuTanT
Master Clock
200 MHz
XTAL Oscillator
FPGA
Trigger Logic


10 000 to 20 000 channels
1152 channels
1152 channels
1152 channels
AsAd
AsAd
AsAd
Trigger level 2
Multiplicity
TimeStamp
Clock
10-20 Optical
Gigabit Ethernet Link
Integration Board
(New Board, Ethernet Switch)
{ Data server : ICE,
ControlHost, ... others }
....etc
SlowControl
RunControl
Event
Builder
CPU
Data
Data
Base
Storage
External to GET (MSU, GANIL,RIKEN, GSI ....)
GET SYSTEM

Synthesis of the AGET requirements

Parameter	Value
Polarity of detector signal	Negative or Positive
Number of channels	72
External Preamplifier	Yes; access to the filter or SCA inputs
Charge measurement	
Input dynamic range	120 fC; 1 pC; 10 pC
Gain	Adjustable/(channel)
Output dynamic range	2V p-p
I.N.L	< 2%
Resolution	< 850 e- (Charge range: 120fC; Peaking Time: 200ns; Cinchannel. < 30pF)
Sampling	
Peaking time value	50 ns to 1 µs (16 values)
Number of SCA Time bins	511
Sampling Frequency	1 MHz to 100 MHz
Time resolution	
Jitter	60 ps rms
Skew	< 700 ps rms
Trigger	
Discriminator solution	L.E.D
Trigger Output/Multiplicity	OR of the 72 discriminator outputs; Width=2*TSCAckread
Dynamic range	5% of input charge range
I.N.L	< 5%
Threshold value	4-bit DAC/channel + (3-bit + polarity bit) common DAC
Minimum threshold value	≥ noise
Readout	
Readout frequency	20 MHz to 25 MHz
Channel Readout mode	Hit channel; specific channels; all channels
SCA Readout mode	511 cells; 256 cells; 128 cells
Test	
calibration	1 channel / 72; external test capacitor
test	1 channel / 72; internal test capacitor (1/charge range)
functional	1, few or 76 channels; internal test capacitor/channel
Counting rate	
ASIC level	< 1 kHz
Power consumption	
Channel | Asic	< 10 mW / channel
Packaging	Ceramic or plastic
Temperature	ambient

ADDITIONAL PHYSICS CAN BE COVERED BY TPC

The TPC also can serve as an active target both in the magnet or as a standalone device

Traditional EOS Study

- Multifragmentation of Participant Zone

TPC is ideal 4π detector.

Good acceptance for all Z

Coherent analysis of numerous observables

Fix A_{tot}, Plot vs. E/A -- Minimize finite-size effects

Can be used as a replacement of well used 4π Detector like INDRA, ISiS and so on.

EOS TPC has already shown the capability.

Symmetry Energy

Besides π^-/π^+ ratios

- Pion flow
- Neutrons & Protons

Relative energy spectra

Differential flow

Balance energy

- Charged Fragments

$t/^3He$ ratio, $^3He/^4He$ ratios,

$^6Li/^7Li$ ratios, $^6He/^6Li$ flow

Fission
Asymmetry dependence of fission barriers

- Using H, He gas in TPC

Track to find interaction point (*E*). *Get the entire* excitation function at one bombarding energy

Multi-particle Final State

- Looking for New kinds of Cluster states like $^{12}Be \rightarrow {}^{6}He + {}^{6}He$

- Coulomb dissociation into p+HI(neutron-rich)

Large relative energy can be covered by TPC.

Nuclear Structure Experiments - (Active Target)

- Inelastic Scattering at intermediate energies
  - (p,p') or (α,α') inverse kinematics, 100-200MeV/n

    precise information on decay branch.
  - Giant resonance studies to access nuclear compressibility

    We should use lower energy beam!!

    <100 MeV/nucleon

- Charge Exchange Reactions
  - AZ(p,n)A(Z+1), AZ(^{3}He,t)A(Z+1) AZ(d,^{2}He)A(Z-1)

Announcement

- We are going to hold an international symposium on “symmetry energy” in last week of July 2010.

- Please join SAMURAI-TPC project